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Commentary

The challenge of accurate spinal growth assessment in the treatment of early onset scoliosis with growth-friendly systems

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All scoliosis treatments in children share the common goal of maximizing control of deformity progression, while minimizing the risk of negative impact in the short and long-term. Early onset scoliosis (EOS), a rare collection of multiple scoliosis types (idiopathic, congenital, neuromuscular, and syndromic) in children younger than 10 years of age, often with other diagnoses and comorbidities, presents certain challenges to treatment that can affect both morbidity and mortality [1−11]. While nonoperative treatments like bracing or cast techniques are attractive in EOS, in that they offer the potential control of deformity progression in a reasonably physiologic manner (by preserving growth, motion, and function of the spine), they are often not effective or definitive. Surgical treatments, like instrumented spinal fusion, though maximally invasive, are attractive in more mature patients as these offer definitive correction and control of deformity, but are less physiologic in that they sacrifice normal growth, motion, and function of the spine. The elimination of growth is problematic in EOS, where extensive spinal fusion can not only limit vertical thoracic spine growth, resulting in short trunk deformity, but can also hinder chest and lung development, resulting in more profound issues like thoracic insufficiency syndrome [1−4].

Alternatives to extensive fusion surgery include strategies that limit the fusion (eg, selective thoracic fusion) delay fusion (eg, growing rods), or avoid fusion altogether (eg, anterior vertebral tethering). Temporizing measures that delay fusion have been used most extensively in EOS as these allow the most predictable control of deformity progression with continued growth during a critical period of development. Growth-friendly techniques include posterior spine or rib-based distraction using traditional growth rods (TGR), magnetically-controlled growth rods (MCGR), or the Vertical Expandable Prosthetic Titanium Rib (VEPTR) as well as posterior growth guidance using Luque trolley or Shilla [12−25]. Despite the significant evolution of these techniques over the past two decades, with greater effectiveness, fewer complications, and an overall reduction in procedures, the true impact of these treatments on growth remains poorly understood [5−11].

The study entitled "A Comparison of Growth among Growth-Friendly Systems for Scoliosis: A Systematic Review" is the first meta-analysis of original articles published from 1984 to 2017 that report on spinal growth in surgically treated EOS [26]. The stated purpose of the study was twofold: (1) to analyze the different methods of growth measurement used in these multiple studies; and (2) to compare the spinal growth achieved with various growth-friendly strategies (single and dual TGR, MCGR, VEPTR, Luque trolley, and Shilla). The measurements used to assess growth in these studies included different spine segments (T1−S1, T1−12, and instrumented length) assessed with different techniques (spinal length, spinal height, and free hand) spanning different time periods (true spinal growth, follow-up spinal growth, and total spinal growth). While the authors performed an extensive review of the literature and provided a thorough analysis of the limitations of current methods of spinal growth measurement, the goal of a state of the art meta-analysis (which is to guide clinical decision making) was not achieved. The "impediments" to achieving this goal were many but primarily related to a lack of uniformity and consistency in measuring and reporting data. These inaccuracies often made the interpretation of results within a given study difficult and meaningful comparison between studies impossible.

The authors performed a systematic literature review that identified 52 articles as acceptable for inclusion. All etiologies of EOS treated with growth-friendly systems were included with an age-range restriction of 5 to 10 years old at the time of the index procedure. Two independent

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reviewers graded the quality of the articles and though the scores were relatively low for nonrandomized studies, the ICC was good. Of the 52 articles included, the majority reported on single or dual TGR (26) followed by MCGR (12), VEPTR (6), Luque trolley (3), and Shilla (1) with three additional articles comparing systems, Shilla versus TGR (2) and MCGR versus TGR (1).

Of the three spine segment measurements used in these studies, T1−S1 was perhaps the most useful in assessing the overall growth of the spine. However, because this measurement included portions of the spine outside of the instrumented segments, it did not accurately reflect growth in the treated portion of the spine. While the T1−12 measurement was attractive as a "proxy" for thoracic growth, it too failed to accurately represent the true treatment effect within the instrumented segments. Measurement of the instrumented segments provided a better estimation of the direct treatment effect, but lacked important information provided by overall spine and thoracic growth. The most common measurement reported was T1−S1 as a solitary data point in 22 studies combined with T1−12 and with the instrumented segment length in 15 and 8 studies, respectively. Unfortunately, no study included measurement of all three segments. Ideally, all the three spine segments should be measured and included.

The specific technique used to measure different spinal segments (spinal length, spinal height, and free-hand) was often poorly described or absent in the studies reviewed. This potentially had a significant but unknown impact on the accuracy of these growth measurements, as each of these techniques could yield a different value for the same deformity and each could change by a different amount with an intervention. Though the free-hand technique was identified as the most accurate method and the least likely to be confounded by an intervention, it was unclear how often it was used over other methods in these studies.

Though true spinal growth, measured after the initial surgery and before the final correction and fusion, was perhaps the best representation of actual growth provided by a growth-friendly system, additional time points were often included that clouded the clarity of results of many studies and made comparisons difficult. Total spinal growth was the broadest but most inaccurate method used in assessing growth as it included lengthening from the index procedure (often called "growth") and from the final correction and fusion. Follow-up spinal growth eliminated the initial procedure but still included the correction and lengthening achieved at final fusion. True spinal growth, reported in only 4 articles, revealed a T1−S1 growth rate of 0.6 cm per year with 2 articles demonstrating a T1−12 growth rate of 0.3 cm per year and an instrumented segment growth rate of 0.9 cm per year. Though it would not be unexpected for these growth rates to be decreased in comparison to Dimiglio's normal spine growth data (T1−S1 growth rate of 1 cm per year from age 5−10 years)—due to significant spinal deformity, multiple surgical interventions, and even comorbidities—interpretation of these values must be made with caution given the extent of issues of inaccuracy discussed above [27].

Other measurements that were even less accurate were used to compare the growth between techniques. Follow-up spinal growth, while less accurate than true spinal growth, was used most frequently, in 47 articles, and yielded growth rates in a relatively normal range (0.7−1.1 cm per year) that were greatest for TGR in both T1−S1 and T1−12 but most significant for MCGR across the instrumented segment. Total spinal growth which, again, is the least accurate measurement, was greatest for MCGR T1−S1 but the MCGR articles were found to have older patients and shorter follow-up. The authors admit that comparisons between these growth-friendly systems are "inadequate."

Despite the inaccuracies in absolute measures of growth in these multiple studies, the authors did demonstrate a proportional change in spinal length that was most significantly impacted by the index procedure and final fusion. By combining data from multiple studies, the authors demonstrated a 40% increase in T1−S1 length due to the initial procedure and a 24% increase due the final procedure for an overall lengthening effect of 64% not related to growth. With only 36% of overall lengthening related to the growth, the authors suggest re-evaluation of the risks and benefits of multiple lengthening procedures.

The authors of this study, while likely frustrated by their findings, have achieved something significant by defining a problem that impacts the accurate assessment of spinal growth after growth-friendly treatments of EOS. Although much has been achieved with the evolution of growth-friendly treatments over the past two decades, greatly reducing morbidity and mortality, a meaningful comparison of growth achieved with various techniques is still not possible due to a lack of uniformity in measuring and reporting data. Going forward, agreement on universal measurements would improve the accuracy of growth assessments and allow meaningful comparisons between techniques. Ideally, this would include true spine growth measured with a single technique (free-hand most accurate) across T1−S1, T1−12, and the instrumented segments. Calculation of vertebral growth per year in all parts of the spine would then be possible, including thoracic versus lumbar, instrumented versus uninstrumented and even inside and outside the region of deformity. With more thorough and accurate universal measurements, additional patient and treatment related factors that impact growth could be analyzed more effectively.

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